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Middle Creek
Dam, Bozeman,
Montana, Gallatin
County, MT-18

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

MIDDLE CREEK DAM
BOZEMAN, MONTANA
GALLATIN COUNTY
MT-18

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PREPARED FOR:

HONORABLE THOMAS L. JUDGE
GOVERNOR, STATE OF MONTANA

STATE OF MONTANA
(OWNER)
MIDDLE CREEK WATER USERS ASSOCIATION
(OPERATOR)

PREPARED BY:
CH2M HILL
BELLEVUE, WASHINGTON

APRIL 1980

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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers, and with representation from the Corps, the State of Montana Department of Natural Resources and Conservation, and the Middle Creek Water Users Association, CH2M HILL inspected Middle Creek Dam on June 8, 1979, under the authority of Public Law 92-367. The dam is located on Hyalite Creek (Middle Creek) in Gallatin County, about 15 miles south of Bozeman, Montana.

This report was compiled from information obtained during an onsite inspection, review of construction plans, and analysis of available hydrologic information. Findings were compared with engineering criteria that are currently accepted by most private and public agencies engaged in dam design, construction, and operation.

FINDINGS AND EVALUATION

Middle Creek Dam is owned by the State of Montana and is operated by the Middle Creek Water Users Association. The dam and reservoir are located on public land administered by the U.S. Forest Service. Middle Creek Reservoir, commonly known as Hyalite Reservoir, is used primarily for storage of irrigation waters, but also is used for recreation and as a supplemental source of municipal water supply for the City of Bozeman and Montana State University. Use of national forest land for such purposes is through Special Use Permits.

The 106-foot-high earth dam impounds 10,230 acre-feet of water at dam elevation 6709.2 feet National Geodetic Vertical Datum (NGVD), previously Mean Sea Level (MSL). This corresponds to elevation 209.2 on the construction plans, which is 0.8 feet lower than the design crest elevation of 210. On the basis of criteria in U.S. Army Corps of Engineers Recommended Guidelines for Safety Inspection of Dams (Ref. 1), the project is large in size. The dam is located such that its failure would endanger many lives and cause extensive property damage. However, no dam breach analysis or routing of a dam breach flood was made for the downstream area. The conclusions on probable damage are based on a brief field visit and engineering judgment.

The project is classified as having a high (Category 1) downstream hazard potential. Inspection criteria (Ref. 1) recommend that a large-sized project with a high downstream hazard potential be capable of safely handling the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

An estimated PMF was developed for the 27.8-square-mile drainage basin. The PMF resulting from the 72-hour general storm has an estimated volume of 27,500 acre-feet and a peak flow of 92,000 c.f.s. The spillway has a maximum discharge capacity of 5,600 c.f.s. with no flashboards and with the reservoir at dam crest, elevation 6709.2 feet NGVD. Routing of the estimated PMF was started with the reservoir at spillway crest, elevation 6698.75 feet NGVD, and no flashboards in place. Routing indicates that the dam is overtopped during the PMF when approximately 29 percent of the total flood volume enters the reservoir. Consequently, the project's spillway is considered seriously inadequate. The dam is constructed of materials that would quickly erode when overtopped by floodwaters.

The relatively flat embankment slopes, the embankment zoning, and the possibility of low water levels in the embankment, suggest that stability may conform with the recommended guidelines. Verification of this finding is required.

The spillway concrete is badly deteriorated, and the reservoir is operated to minimize spillway use.

On the basis of the field inspection and preliminary hydrologic analysis, Middle Creek Dam does not now conform to inspection guidelines with respect to discharge and/or storage capacities to safely handle the recommended spillway design flood, thus leading to potential for loss of life and property destruction. Because the project cannot safely handle one-half the recommended PMF, it is considered unsafe until the recommended actions are accomplished.

RECOMMENDATIONS

A downstream warning system, for use in the event of possible dam overtopping or structural failure, must be developed and implemented immediately. Remove flashboards from the spillway. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

Investigate source of left abutment seepage by the installation of piezometers and study of the data. Sample and test the embankment and foundation soils and conduct stability analyses using piezometric data.

Conduct periodic inspections of the facility at intervals not to exceed 5 years by engineers experienced in dam design and construction.

Richard L. Foster
Professional Engineer

PERTINENT DATA

1. GENERAL

Federal ID No.	MT-18
Owner	State of Montana
Operator	Middle Creek Water Users Association
Date Constructed	1951
Purpose	Irrigation, Water Supply, and Recreation
Location	Section 15, 16, 22, 23, T45, R6E, Principal Meridian
County, State	Gallatin County, Montana
Watershed	Hyalite (Middle) Creek, a tributary of the Gallatin River
Downstream Hazard Potential	Category 1 (High)
USGS Quadrangle	Fridley Peak

2. RESERVOIR

Surface Area at Spillway Crest, Elevation 6698.75 feet NGVD	200 acres
Drainage Area	27.8 square miles
Storage at Spillway Crest, Elevation 6698.75 feet NGVD	7,780 acre-feet
Storage at Dam Crest, Elevation 6709.2 feet NGVD	10,230 acre-feet
Surcharge Storage	2,450 acre-feet

3.	SPILLWAY	
	Type	Uncontrolled concrete chute
	Crest Width	40 feet
	Crest Elevation	6698.75 feet NGVD
	Capacity with Reservoir at Dam Crest	5,600 c.f.s.
4.	OUTLET WORKS	
	Control Tower	Reinforced concrete, 10 feet in diameter, 112 feet high
	Conduit	60 inches in diameter, steel-lined, concrete
	Conduit Length	600 feet
	Valves	One gate valve, 54 inches in diameter and one butterfly valve, 54 inches in diameter.
	Capacity with Reservoir at Dam Crest, Elevation 6709.2 feet NGVD	830 c.f.s.
5.	DAM	
	Type	Rolled earthfill
	Length	1,300 feet
	Crest Width	40 feet
	Design Crest Elevation (Corresponds to 210 on Construction Plans)	6710 feet NGVD
	Measured Crest Elevation (Corresponds to 209.2 on Construction Plans)	6709.2 feet NGVD
	Hydraulic Height (Crest to Toe)	106 feet

Upstream Slope	1 V on 2 H, 1 V on 3 H, 1 V on 4 H (Refer to Plate 7)
Downstream Slope	1 V on 2 H, 1 V on 4 H (Refer to Plate 7)

Chapter 1
BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Middle Creek Dam, owned by the State of Montana.

The National Dam Inspection Act, Public Law 92-367 dated August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-Federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many Federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigation and evaluation of existing dam conditions, so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam.

(2) based upon an evaluation of the available data and a visual inspection.

(3) performed to determine if any needed emergency measures and/or if additional studies, investigations, and analyses are necessary or warranted.

(4) not intended to include extensive explorations and analyses or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing,

material testing, hydraulic and hydrologic analyses, and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases, the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigation outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-Federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on a June 8, 1979, brief visual inspection of the project, and a detailed review of available construction plans. Inspection procedures and criteria were those established by the Recommended Guidelines for Safety Inspection of Dams (Ref. 1).

Personnel present during the inspection included:

R. D. Eckerlin, Geologist, Corps of Engineers
Larry Tegg, State of Montana Department of Natural Resources and Conservation
Robert A. Clark, State of Montana Department of Natural Resources and Conservation
Dick Boylan, President, Middle Creek Water Users Association

Glenn Kraft, Middle Creek Water Users Association
George Dusenberry, Middle Creek Water Users Association

CH2M HILL personnel who participated in the field inspection and contributed to this report are:

Miles C. Bubenik, Geotechnical Engineer, Team Leader
Jerry Jacksha, Geotechnical Engineer
Loren Bottorff, Hydrologist/Hydraulics Engineer

This report has been reviewed by the State of Montana Department of Natural Resources and Conservation (DNRC), the Middle Creek Water Users Association, and the U.S. Forest Service. Agency comments are enclosed in the Appendix of this report.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Middle Creek Dam is located on Hyalite Creek, a tributary of the Gallatin River, in Gallatin County, Montana, approximately 15 miles south of the City of Bozeman (see Plate 1). The dam is currently listed as having high downstream hazard potential and the Federal identification number is MT-18. The 106-foot-high, 1,300-foot-long dam, completed in 1951, impounds 10,230 acre-feet at dam crest, elevation 6709.2 feet NGVD. Based on a visual reconnaissance and engineering judgment, a Forest Service campground and agricultural lands downstream could be affected by a sudden breach of the dam. According to information received from the U.S. Forest Service, the campground is used year-round with heavy use from the beginning of July through Labor Day each year. The Forest Service estimates about 25 people per day as the average use for the campground during the peak months.

The 200-acre reservoir is used for water supply, recreation, and irrigation storage. Although the project is owned by the State of Montana, operation and maintenance are performed by the Middle Creek Water Users Association.

The 90-foot-long, 40-foot-wide uncontrolled spillway structure is located adjacent to the right abutment, as shown in Photo 1 and Plate 2.

The 5-foot-diameter low-level outlet conduit is located about 450 feet from the left abutment, and the two 54-inch valves are controlled from the tower at dam crest, as shown in Photo 6 and Plate 6.

1.2.2 Regional Geology and Seismicity

The information in paragraphs 1.2.2 and 1.2.3 was taken from a memorandum by R. D. Eckerlin (Ref. 5).

Middle Creek Dam and Reservoir are located on Hyalite Creek within the Gallatin Range in the Northern Rocky Mountains physiographic province. The East and West Forks of Hyalite (Middle) Creek flow into Middle Creek Reservoir. The elevation of the reservoir is about 6700 feet NGVD and its drainage area reaches an elevation of 10,300 feet NGVD. Approximately 1 mile downstream from the dam, Hyalite Creek flows through a narrow rock canyon 8 miles in length, with a gradient of approximately 140 feet per mile. At the foot of the Gallatin Range, the creek has slightly incised into the Bozeman alluvial fan.

The Gallatin Range and Madison Range, to the west, are one complex mountain unit arbitrarily separated by the canyon of the Gallatin River. These ranges are composed of Precambrian gneiss and some infaulted blocks of Paleozoic and Mesozoic sedimentary rocks. Much of the mountain area has been subjected to Pleistocene and Recent alpine glaciation. Approximately 20 percent of the Madison-Gallatin area has been subjected to Recent age mass-gravity movement, including debris slides, slumps, rockslides, and earthflows. Factors conducive to sliding in the northern Gallatin Range are:

- Significant valley glaciation causing oversteepened valley slopes.
- Relatively weak or poorly consolidated rock materials resting at high elevations.
- A structurally complex area with steeply dipping planes of foliation, bedding, and fractures.
- The area is situated in a region subjected to frequent earthquakes.

Middle Creek Reservoir is located in a Recent age glaciated valley. Ice formed as small alpine glaciers at the headwaters of the East and West Forks of Hyalite Creek. This is indicated by small cirques perched high on the north and northeastern slopes of Hyalite Ridge. Glacier ice tongues extended down each fork and coalesced at the upstream part of Middle Creek Reservoir. The northwest ice limit coincides closely with the entrance into Hyalite Canyon located about one mile downstream from the dam. Only about 25 percent of the inferred areal extent of outwash is preserved--in numerous small terrace remnants and in a large terrace deposit that borders the northeast portions of the reservoir.

The dam lies in a zone that is seismically active. Algermissen (Ref. 6) indicates this zone could expect a maximum modified Mercalli intensity X event, or an

equivalent 7.3 magnitude event, and that this is likely in the next 100 years. A probability estimate of 0.4g horizontal bedrock acceleration has a 90 percent likelihood of not being exceeded in 50 years. It is estimated that the dam experienced a greater than 0.2g bedrock acceleration during the 1959 Hebgen Lake earthquake.

The inspection guidelines (Ref. 1) seismic zoning map shows that the site is in Zone 3, which has a potential for major earthquake damage. Although the zoning map is based on a known distribution of damaging earthquakes, it does not necessarily reflect accurate or adequate seismic design parameters for this site.

1.2.3 Site Geology

Middle Creek Dam appears to be founded on a mixture of valley glacier sediments and landslide deposits from lower Cretaceous shales and mudstones forming the valley slope to the west. Thirteen preconstruction borehole logs, to about 50 feet in depth, drilled in the embankment foundation, show the valley sediments to be heterogeneous deposits of boulders, gravel, clay, clay with broken rock, and "conglomerate."

The right (northeast) abutment is presumed to be founded on glacial terrace materials composed of clay, sand, gravel, and boulders. The left (southeast) abutment appears to be founded on mixed landslide and glacial deposits composed of clay, silt, sand, poorly sorted gravel, rock fragments, conglomerate, and boulders. The boulders are composed of volcanic rocks, granite, gneiss, and limestone.

Recent age glacial outwash, composed of coarse bouldery gravel, sand, and clay, occurs in scattered terrace remnants around the reservoir periphery. Terrace surfaces appear to reach a maximum of about 500 feet above the reservoir.

The reservoir shoreline varies from gentle to near vertical slopes standing about 30 feet above the reservoir surface. Wave erosion of the reservoir slopes is present and occasional minor shoreline caving occurs on the steeper shoreline slopes. Mesozoic shales and mudstones are present in higher elevations along the west valley side and these formations are susceptible to major landsliding.

1.2.4 Design and Construction History

The Middle Creek project, designed and constructed by the State of Montana Department of Natural Resources and Conservation, lies in large part on Forest Service lands and was constructed and is operated under a special use permit.

Construction was initiated in 1939, stopped in June 1941, resumed in 1948, and completed in 1951. Remedial work was accomplished in 1956 to reduce and control seepage in the left abutment. This latest work included the construction of an upstream impervious blanket and the installation of a toe drain. Plates 2, 3, 4, 6, 7, 8, 9 and 10 have been developed from information on file with the State of Montana, Department of Natural Resources and Conservation.

Chapter 2

INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The spillway for Middle Creek Dam is located at the right abutment. The unlined approach channel to the spillway is short and unobstructed and is crossed by a log boom. The ends of the boom are anchored only slightly higher than the spillway crest, which will prevent the boom from functioning properly during high spillway discharges.

The uncontrolled concrete crest is formed to an ogee shape of approximately 6-foot design head. The apex of the spillway crest is at approximate elevation 6698.75 feet NGVD (corresponds to assumed elevation 198.75 feet on construction plans) 10.4 feet below the low point on the dam crest. Pipes are embedded along the apex of the spillway crest for the installation of flashboards. Wooden flashboards held by metal pipe supports were in place to 2 feet above the spillway crest at the time of the inspection. The spillway crest is 40 feet wide and contains no piers, other than the flashboard supports. The left (looking downstream) spillway abutment is rounded at a 10-foot radius and a wing wall extends upstream at a 45-degree angle for approximately 24 feet. The right spillway abutment has a wing wall perpendicular to the direction of flow. The spillway crest is crossed by a free-span bridge with 9.5 feet clear between the spillway crest and the underside of bridge.

A hydraulic jump stilling basin is located approximately 75 feet downstream of the spillway crest. The invert of the spillway chute between the ogee crest and the stilling basin changes slope from 0.03 foot per foot to 0.67 foot per foot through a 23-foot vertical curve. The floor of the stilling basin is about 23 feet lower in elevation than the apex of the spillway crest. The stilling basin is 40 feet in length and contains two rows of 3-foot-high baffle piers. A 6-foot-high end sill creates tailwater in the basin during spillway discharge.

Available data are not sufficient to evaluate the adequacy of the stilling basin to effectively dissipate energy associated with spillway flows.

The downstream channel near the stilling basin is well riprapped and is neither eroding nor backcutting. The

discharge channel enters Hyalite Creek approximately 3,000 feet downstream of the spillway after a cumulative drop of approximately 170 feet. The entire length of the channel was not walked during the inspection, but previous inspection reports indicate that some sections are heavily eroded. However, the channel is sufficiently removed from the dam, and erosion will not affect the safety of the dam.

Where visible, the concrete of the stilling basin is deteriorated (Photo 5), probably because of freeze/thaw occurrence. The stilling basin walls, end sill, and baffle piers show cracking, exposed reinforcement, and extensive spalling. A spalled area on the right (looking downstream) stilling basin wall was seeping water. The floor of the stilling basin was covered with water, rock, soil, grass, and other debris, so the condition of the concrete could not be observed at the time of the inspection.

The spillway rating was developed, with the flashboards removed, by using the weir head-discharge relationship with head-dependent discharge coefficients varying from about 3.3 to 4.1. The coefficients are for an ogee crest with a weir height to design head ratio of 0.6. The maximum discharge capacity of the spillway, with flashboards removed and with the reservoir at top of dam elevation 6709.2 feet NGVD, was estimated to be 5,600 c.f.s. The spillway chute is estimated to just contain the maximum spillway discharge with the pool at dam crest, elevation 6709.2 feet. The discharge rating curve, with flashboards removed, is presented on Plate 5. The flashboards were apparently designed to fail when about 3 feet of water passes over the tops of the boards; however, an analysis of the design was not conducted during this dam safety study.

2.1.2 Outlet

The outlet works for Middle Creek Dam is located through the embankment near the left abutment. At the time of our inspection the intake structure could not be inspected because of the high reservoir water surface level. The construction plans do not show the actual configuration. The 60-inch-diameter steel-lined conduit is about 600 feet in length. A gate tower is located about 250 feet downstream of the intake structure. The gate tower is covered by a locked gatehouse and is reached by a catwalk from the crest of the dam. The control for the 54-inch-diameter emergency gate valve is located at the bottom of the tower, and the control for the 54-inch-diameter operating pivot butterfly valve is located at the top of the tower. The construction plans do not show a profile through the outlet works, so invert slopes are not known. The circular steel liner ends approximately 100 feet upstream from the end of the conduit.

From this point, the conduit continues as a 60-inch-diameter straight-legged horseshoe concrete section.

The outlet structure consists of a pair of diverging wing walls that change from vertical at the portal to 1 H on 1 V approximately 20 feet downstream of the portal (Photo 8). Discharge from the outlet works makes a sweeping turn to the right (looking downstream) from the outlet structure. Erosion has occurred along the left bank for a distance of approximately 200 feet downstream of the outlet. The bank is approximately 40 feet high at the highest point. However, this erosion does not pose a threat to the safety of the dam.

The emergency valve was closed during the inspection, and the operating valve was opened so the seats could be viewed. Difficulty was experienced in closing the operating valve after the inspection, because one of the pedestal anchor bolts pulled out of the concrete. Minor cavitation damage was observed on the top deflector of the operating valve and this damage was repaired by the Water Users Association at the time of the inspection with epoxy steel. Areas previously treated with epoxy steel appeared to be serving well. The steel liner of the conduit appeared in very good condition; its bituminous lining was missing in only a few places.

The discharge rating for the outlet works was developed with both valves fully open. A Manning's "n" of 0.012 was used to estimate friction losses with the conduit flowing full. As a profile of the outlet works was not available, the elevation of the conduit invert at the outlet structure was assumed from a contour map to be 6597.5 feet NGVD. The maximum discharge capacity of the outlet works, with the reservoir at top of dam, elevation 6709.2 feet NGVD, was estimated to be 830 c.f.s.

2.1.3 Freeboard

The term freeboard is applied to the vertical distance between the maximum reservoir water elevation and the dam crest. Because the dam overtops during the probable maximum flood (PMF: see paragraph 2.2.4), it has no freeboard. The vertical distance between the low point on the dam and the reservoir level at the time of the inspection was 10.7 feet. The spillway crest is 10.4 feet below the low point on the dam crest, but presently flashboards are installed to 2 feet above the spillway crest. The crest of the dam varies 0.8 feet in elevation along its 1,300-foot length. The effective fetch for wind-generated waves is about 0.5 of a mile and wave runup on the embankment is estimated to be about 3 feet. Although the dam will overtop during the PMF, the vertical distance between the dam crest and the normal

reservoir water surface level is adequate to prevent overtopping the embankment by wind-generated waves during normal conditions.

2.2 HYDROLOGY, CLIMATOLOGY, AND PHYSIOGRAPHY

2.2.1 General

The climate of the area is continental in nature, characterized by warm summers and cold winters. The nearest climatological station (elevation 4856 feet NGVD) is at the Bozeman Montana State University, about 13 miles north of Middle Creek Dam. Mean annual precipitation at the station is 18.7 inches with 48 percent falling in April through July. Mean February precipitation is 0.65 inches and mean June precipitation is 3.22 inches. Mean annual precipitation on the Middle Creek Dam drainage basin is probably near 20 inches. Mean annual temperature at Bozeman is 43.1 degrees Fahrenheit (F); mean January temperature is 20.8 degrees F; and mean July temperature is 66.4 degrees F. Temperatures in the Middle Creek Dam drainage basin probably average about 10 degrees cooler than Bozeman. Summer temperatures can exceed 100 degrees F, and winter temperatures can dip well below 0 degrees F. Winters have few extended cold spells; periods of warm, windy "chinook" weather occur between cold periods.

The drainage basin area for Middle Creek Dam is 27.8 square miles and is roughly oval in shape. The basin elevations range from 6,700 feet at the dam to 10,330 on the southern drainage boundary. The basin is mountainous and about 80 percent forested. The West Fork of Hyalite Creek is the main inflow stream to the reservoir, but it drains only about 45 percent of the basin. The stream drops an average of 390 feet per mile over its 6-mile length above Middle Creek Reservoir. The remainder of the basin is drained by Flanders Creek and the East Fork of Hyalite Creek.

In 1974, the State of Montana DNRC installed two stream-gaging stations above the reservoir: one on the East Fork and one on the West Fork of Hyalite Creek. A USGS stream-gaging station is located on Hyalite Creek downstream of the reservoir but has a drainage area about 20 square miles larger than the drainage area above Middle Creek Dam. This gaging station recorded a maximum flow of 956 c.f.s. in June 1898. The spillway was designed for a maximum flow of 3,000 c.f.s., based on a Meyers coefficient of 600 in the formula: $Q = (\text{drainage area})^{0.5} \times 600$.

2.2.2 Reservoir Storage and Spillway Discharge

The reservoir has a surface area of 200 acres and a storage area of 7,780 acre-feet at spillway crest, elevation 6698.75 feet NGVD (no flashboards). Approximately 2,450 acre-feet of surcharge storage is available in the reservoir between the spillway crest and the dam crest. The spillway discharge with the reservoir at the dam crest is 5,600 c.f.s., about 460 acre-feet per hour.

2.2.3 Estimated Probable Maximum Flood

The probable maximum flood (PMF) is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. An estimate of the PMF was made during this dam safety analysis and was routed through the reservoir.

The procedure contained in U.S. Weather Bureau's Technical Paper 38 (Ref. 2) was used to compute the probable maximum precipitation (PMP). This storm, for the 27.8-square-mile basin, produces 11.3 inches in 6 hours and 15.3 inches in 24 hours. The 72-hour precipitation was estimated to be 17.7 inches.

As an alternative to computing snowmelt and assigning an infiltration rate, a ground condition with no infiltration losses was assumed during the entire flood. This is possible because minimum infiltration losses during snowmelt are approximately offset by the melt. A base flow of 200 c.f.s. was used for the entire flood.

A triangular unit hydrograph for a 30-minute rainfall duration was developed for the 27.8-square-mile drainage basin by procedures outlined in Design of Small Dams (Ref. 3). A curvilinear fit of the triangular unit hydrograph was used. The PMP was applied to the unit hydrograph by means of the computer program, HEC-1 (Ref. 4). This estimate of the PMP produced a flood with a peak flow of 92,000 c.f.s. and a volume of 27,500 acre-feet.

2.2.4 Flood Routing

The PMF was routed through the reservoir by using the computer program HEC-1 (Ref. 4). The reservoir level was assumed to be at the spillway crest, with flashboards removed, at the beginning of the PMF. The outlet works was assumed to be fully open during the entire flood. The routing shows that the dam will be overtopped during the PMF when approximately 29 percent of the total flood volume enters the reservoir. Floods much smaller than the PMF could overtop and fail the dam. Since the dam is overtopped with the

above routing, no routing was done with flashboards installed or with the outlet works closed. Routing under these conditions may reduce the percentage of overtopping by about 10 percent.

2.3 GEOTECHNICAL EVALUATION

2.3.1 Dam

The 106-foot-high zoned earthfill dam is 1,300 feet long and has a 40-foot crest width at the design crest elevation of 6710 feet NGVD, which corresponds to elevation 210 feet of an assumed datum used in the construction drawings (see Plate 7). The upstream slope varies from 1 V (Vertical) on 2 H (Horizontal) between elevations 6710 feet NGVD and 6700 feet NGVD; 1 V on 3 H between elevations 6700 feet NGVD and 6662 feet NGVD; and 1 V on 4 H between elevation 6662 feet NGVD and 6624 feet NGVD, or toe of the slope. The downstream slope is 1 V on 2 H between the crest and elevation 6630 feet NGVD, except for a 10-foot-wide bench at elevation 6670 feet NGVD. Between 6630 feet NGVD and 6610 feet NGVD, the slope changes to 1 V on 4 H. An impervious zone is shown between the upstream slope and a 1 V on 1 H slope that starts at a point on the crest 5 feet downstream of dam centerline and slopes upstream to elevation 6624 feet NGVD, the elevation where dam construction was terminated in 1941.

When construction resumed, in the summer of 1948, the dam centerline was moved downstream 38 feet. Reasons for this change are not documented; however, plans show that prior construction stripped and replaced foundation soils from beneath the upstream impervious section, as shown on Plate 7. A central semi-impervious zone lies adjacent to the upstream impervious zone and is defined downstream by a 1 V on 1 H slope. Plans show a downstream pervious zone extending to the downstream slope. A cutoff trench was excavated at the upstream third point to depths varying from a few feet to as much as 50 feet below the original ground surface (see Plate 8). A 12-inch concrete drain tile is located at the downstream midpoint and approximately 7 feet below original groundline. Plans also show that select gravel was placed around the pipe. Gradation of the select material is unavailable.

The deep foundation excavation, the flat (1 V on 3 H and 1 V on 4 H) slopes both upstream and downstream, and boring logs that show yellow and blue soft clays, suggest that the engineer was designing for a low-strength foundation material. The 12-inch interior foundation drain shown on Plate 7 is an attempt to lower the phreatic surface in the embankment and reduce uplift forces in the foundation.

Embankment materials were obtained onsite; however, information on material characteristics, shear strengths, and construction control requirements is no longer available. The downstream zone of the dam embankment is composed of materials that, if overtopped, will rapidly erode and lead to dam failure. Information on foundation conditions that existed prior to construction is shown on Plates 8 and 9 and includes 13 boring logs.

The 5-foot-diameter low-level outlet conduit and control tower are not founded on rock. Invert elevation at the tower location is 6,600 feet NGVD. Information on boring logs (Plates 8 and 9) shows that the conduit foundation consists of both clays and conglomerate.

The upstream slope is protected with a 4-foot thickness of gravel bedding and 2.5 feet of rock riprap. The June 8, 1979, field inspection found the riprap in good condition.

Some scattered trees and brush are growing on the lower slopes, as seen in Photo 12.

Levels taken along the dam crest during the inspection found that 500 feet of the crest near the left abutment are as much as 0.8 feet below the design elevation of 210 feet.

2.3.2 Foundation Conditions, Seepage, and Drainage

Foundation conditions are described in the preceding paragraph and paragraph 1.2.3, Site Geology. Exploration logs show appreciable depths of clay in all borings throughout the length of the cutoff, which extends from the left to right abutments. Cutoff depth is shown to be as much as 50 feet, as shown on Plate 8. Logs also show conglomerate, boulders, and gravels. Pre-construction water levels are not shown on the logs. It is not known whether the cutoff was extended to an arbitrarily selected depth or to an impervious strata.

Plans developed in 1956 show that corrective work was conducted on the left abutment. This work consisted of a 3/4-inch-thick membrane covered with 3 feet of excavated material and the installation of a pipe drain near the downstream toe (Plate 10). Plans show that the membrane extended between elevations 6685 feet NGVD and 6705 feet NGVD. As the spillway crest is at 6698.75 feet NGVD, maximum head on the membrane during normal pool is less than 15 feet. Photo 10 shows flow from a 10-inch-diameter toe drain (Drain No. 1), which was estimated to be 200 to 300 gpm. It was stated that pipe flow is minor until the reservoir reaches the elevation of the blanket.

Plans (Plate 7) show that a 12-inch-diameter concrete pipe drain was constructed near the midpoint of the downstream slope and about 7 feet below original ground elevation. Although plans not included with this report show the location of this drain, the inspection team was unable to locate the point of discharge at the downstream toe. At this time, it is unknown whether the drain was constructed as shown; therefore, its effectiveness in lowering the phreatic surface in the downstream shell is unknown because no piezometers are installed in the dam.

Minor seepage was observed adjacent to the right abutment; however, the snowmelt in progress at time of the inspection may have contributed to this seepage.

2.3.3 Stability

State of Montana Department of Natural Resources and Conservation files contain no information on strength parameters of either the [redacted] clay foundation soils or embankment materials, nor is a stability analysis available. The construction drawings indicate the dam embankment is zoned with the more impervious materials upstream (Plate 7). If the dam was constructed as indicated, then the phreatic surface in the downstream embankment may be low. Also, if the 12-inch interior drain is in place as shown on the plans and operable, it would lower the phreatic surface.

The dam withstood severe seismic loading during the 1959 Hegben earthquake (refer to Paragraph 1.2.2) with no reported distress. It is our preliminary judgment that the dam embankment may conform to inspection guidelines stability criteria, provided the embankment zoning and 12-inch interior drain are effectively lowering the phreatic surface in the downstream embankment. This tentative conclusion must be verified by field investigation of water levels, laboratory testing of the clay foundation soils, and stability analysis.

2.4 PROJECT OPERATIONS AND MAINTENANCE

The facility is owned by the State of Montana Department of Natural Resources and Conservation and is operated by the Middle Creek Water Users Association. Information on operations and maintenance was obtained from discussions with members of the Water Users Association, because a written formal project operation and maintenance program for the dam has not been developed.

2.4.1 Dam

Maintenance of the dam is performed as required. Cavitation damage which occurs at the butterfly valve is periodically repaired with epoxy steel. Minor cavitation damage observed during the inspection was repaired by the Water Users Association at that time. The project appeared to be well maintained. The concrete in the spillway stilling basin was very deteriorated from freeze/thaw action.

The State of Montana DNRC conducts annual inspections of the facility and makes appropriate recommendations for maintenance and repairs. It is the responsibility of the Water Users Association to carry out these recommendations.

2.4.2 Reservoir

Water from Middle Creek Reservoir is used primarily for irrigation, but it is also used as a supplemental source of municipal water supply for the City of Bozeman and Montana State University. The City of Bozeman has rights to 2,500 acre-feet of water over a 90-day period in the summer. Mr. Burt Manry, the dam operator, coordinates water releases with the irrigators and the City of Bozeman. Because of the deteriorated condition of the spillway stilling basin concrete, the reservoir is operated to minimize use of the spillway. The operation plan was developed by the U.S. Soil Conservation Service (SCS) and uses runoff forecasts to maximize irrigation storage, flood control, recreation, and other benefits. Two stream-gaging stations above the reservoir aid in the operation plan.

2.4.3 Warning System

There is no formal downstream warning plan for use in the event of impending dam failure.

Chapter 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of the project in terms of the recommended guidelines' performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification, and Safety Evaluation

In accordance with inspection guidelines, Middle Creek Dam is large in size with a high downstream hazard potential rating. The recommended spillway design flood (SDF) for this project is a full PMF. Because the project can safely handle only approximately 29 percent of the PMF without overtopping and causing the dam to fail, Middle Creek Dam has a seriously inadequate spillway, does not meet inspection guidelines, and is considered unsafe until recommended actions are completed.

3.1.2 Embankment Dam

A brief visual inspection of Middle Creek Dam found no cracking, depressions, or irregularities in the embankment slopes. Levels conducted along the dam crest found that the area approximately 300 to 500 feet from the left abutment is about 0.8 feet below design grade.

With the pool near spillway crest, the toe drain adjacent to the left abutment toe was discharging 200 to 300 gpm. Seepage was also observed adjacent to the right abutment; however, this may have been augmented by the snowmelt.

Construction plans show an interior drain located 7 feet below ground surface and at the midpoint of the downstream slope; however, the inspection team could not find the point of discharge, and it is uncertain whether this drain was actually constructed.

There is no stability analysis on file in the State of Montana Department of Natural Resources and no information on foundation or embankment strength parameters that are required for the analysis.

There are no piezometers or other instrumentation at the dam.

Based on the brief field inspection, a detailed study of construction plans including the boring logs, and a review of the seismic history, it is our preliminary judgment that

embankment stability may conform to inspection guidelines provided the interior zoning and interior drain effectively lower the phreatic surface in the dam. Recommendations are made to verify this preliminary conclusion.

Riprap on the upstream slope adequately protects the embankment against waves generated within the reservoir.

3.1.3 Spillway and Reservoir Capacity

The reservoir has a surface area of 200 acres and a storage of 7,780 acre-feet at spillway crest, elevation 6698.75 feet NGVD. Approximately 2,450 acre-feet of surcharge storage is available in the reservoir between the spillway crest and the dam crest. The maximum spillway discharge, with the reservoir at the dam crest and no flashboards in place, of 5,600 c.f.s. is just contained by the spillway chute. Available data are insufficient to evaluate the adequacy of the stilling basin.

The concrete of the spillway stilling basin is very deteriorated. The basin walls, end sill, and baffle piers show cracking, exposed reinforcement, and very heavy spalling. Also, a substantial amount of debris was observed in the basin, preventing inspection of the basin floor. Both the existing damage and debris present would increase the potential for further damage with spillway use.

3.1.4 Outlet Works

Minor cavitation damage was observed on the top deflector of the operating valve, and this damage was repaired by the Water Users Association with epoxy steel at the time of the inspection. Areas previously treated with epoxy steel appeared to be serving well. The steel liner of the conduit appeared in very good condition; its bituminous lining was missing in only a few places.

3.1.5 Operation and Maintenance

The State of Montana DNRC conducts annual inspections of the facility and makes appropriate recommendations for maintenance and repairs. The Middle Creek Water Users Association is responsible for operation and maintenance. Maintenance of the dam is performed as required. Cavitation damage at the butterfly valve is periodically repaired with epoxy steel. In general, the project appeared to be well maintained, except that the spillway stilling basin concrete was very deteriorated from freeze/thaw action. Because of the deteriorated condition of the concrete, the reservoir is operated to minimize use of the spillway. A plan developed by the SCS uses runoff forecasts to maximize irrigation storage, flood control, recreation, and other benefits. Two

stream-gaging stations above the reservoir aid in the operation plan. There is no formal warning plan for use in the event of impending dam failure.

3.2 RECOMMENDATIONS

For the present project, storage between normal pool and dam crest provides a degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety without decreasing this flood protection.

The findings suggest that high priority be given the following recommendations:

1. Immediately develop, implement, and periodically test an emergency warning plan for use in the event of impending dam overtopping or structural distress.

2. Reposition the log boom so it functions for all reservoir levels.

3. Discontinue use of flashboards in the spillway.

4. Inspect the outlet works intake structure, the conduit upstream from the control tower, and the operating valve pedestal. Make all necessary repairs.

5. Remove the few scattered trees, root systems, and brush from the embankment and toe areas. Backfill and compact all depressions.

6. Periodically remove all debris from the stilling basin.

7. Repair the spillway stilling basin concrete.

8. Develop formal, written operation and maintenance plan.

The above recommendations will not make the dam safe, but will reduce risk to life and property while the following recommended actions are being taken.

9. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

10. Determine the source of left abutment seepage by the installation of piezometers and study of the data. Monitor seepage as related to reservoir levels. Also, install and monitor piezometers in dam to determine position of phreatic surface for stability studies.

11. Conduct stability analyses of the dam embankment and left abutment and place them on file. These analyses must be performed by qualified geotechnical engineers and be based on: seismic and static loading conditions; in situ strength properties of the embankment and foundation materials; and the phreatic surface as determined from piezometric observations. The seismic loads must be based on an assessment of the area, and the project's response to a seismic event evaluated. The material strength properties must be established by drilling, sampling, and laboratory testing.

12. Conduct periodic inspections of the facility at intervals not to exceed 5 years by engineers experienced in dam design and construction.

REFERENCES

1. U.S. Army Corps of Engineers, Office of the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspection of Dams," Washington, D.C., Department of the Army, May 1975.

2. U.S. Weather Bureau, Technical Paper 38, Generalized Estimates of Probable Maximum Precipitation for the United States West of the 105th Meridian, Washington, D.C., 1960.

3. U.S. Bureau of Reclamation, "Design of Small Dams," 2nd Edition, 1974.

4. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Davis, California, January 1973.

5. R. D. Eckerlin, U.S. Army Corps of Engineers, Memorandum on Middle Creek Dam Inspection, 23 July 1979.

6. S. T. Algermissen and D. M. Perkins, "A Probabilistic Estimate of Maximum Accelerations In Rock In The Contigious United States," Bulletin, U.S. Department of the Interior, Open file report, U.S. Geological Survey, No. 76-416, 1976.

Appendix

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872

HELENA, MONTANA 59601

March 26, 1980

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on the Middle Creek Reservoir Dam (MT-18). We concur with the findings and recommendations and feel that the report satisfies the criteria for the Phase I evaluation. Minor comments have been discussed with your staff and we understand that these will be included in the final report.

We sent copies of the final draft report to the Middle Creek Water User Association for comment. They did not want to make a formal reply, but elected instead to discuss their comments with us by phone. Their comments were taken into consideration when we discussed our comments with your staff.

Thank you for this opportunity to review and comment on the final draft report for this project.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB:LT:mb

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FEDERAL BUILDING MISSOULA, MONTANA 59801

(7503)

FEB 1 8 1980

Mr. Sidney Knutson, P.E.
Asst. Chief, Engineering Div.
Seattle Dist., Corps of Engineers
P. O. Box C-3755
Seattle, Washington 98124

Dear Mr. Knutson:

As requested in your letter of 25 January, we have reviewed the draft report on Middle Creek Dam and have the following comments.

1. On page 5, our records show an average summer use of 25 people per day at the campground.

2. We agree with the recommendations in the report.

3. We disagree with the hydrologic parameters used and the conclusions drawn therefrom.

The conclusion that this dam is "unsafe" is premature since proper hydrology, breached dam analysis, and flood routing have not yet been done.

R.W. Larse

R. W. LARSE
Regional Engineer

PHOTO 1 View of spillway and dam from right abutment

PHOTO 2 View of spillway from downstream channel

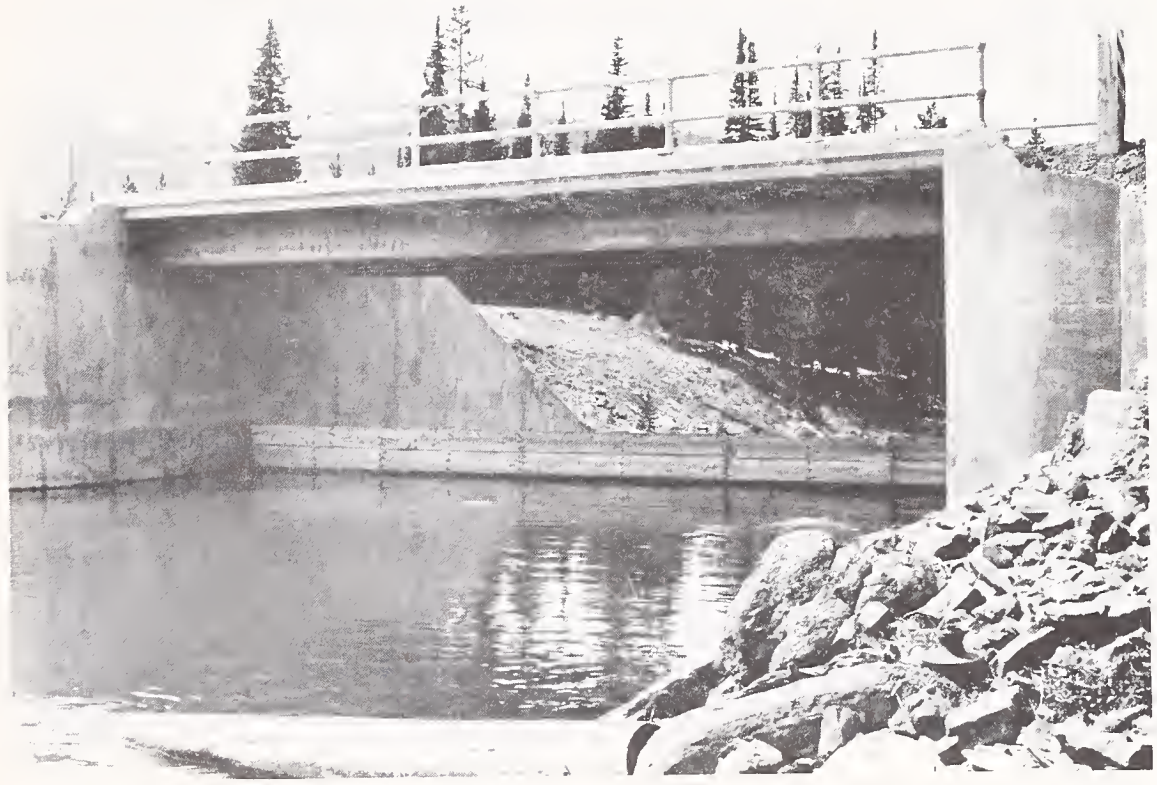


PHOTO 3 View of spillway and stoplogs from upstream right abutment

PHOTO 4 Stilling basin, note wet area on right training wall

PHOTO 5 Closeup of wet, spalled, right stilling basin wall and deteriorated baffles

PHOTO 6 Control tower and access bridge

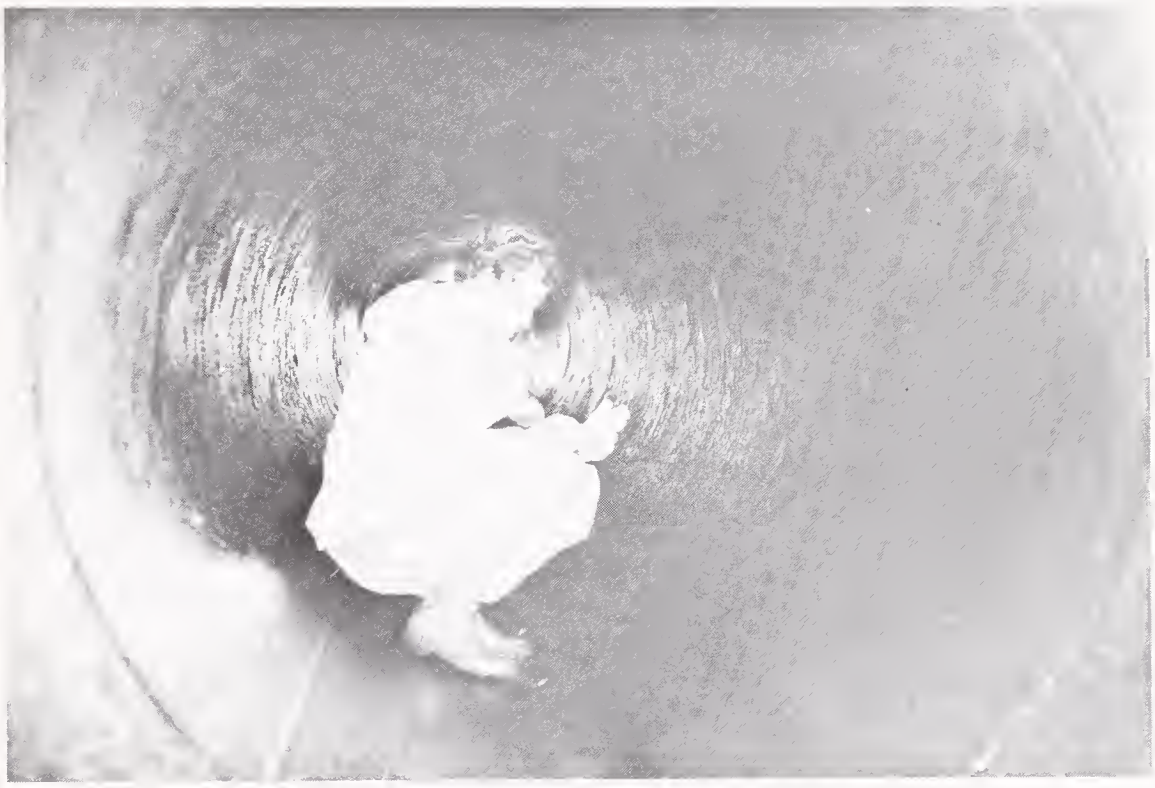


PHOTO 7 Steel lined section of low level conduit

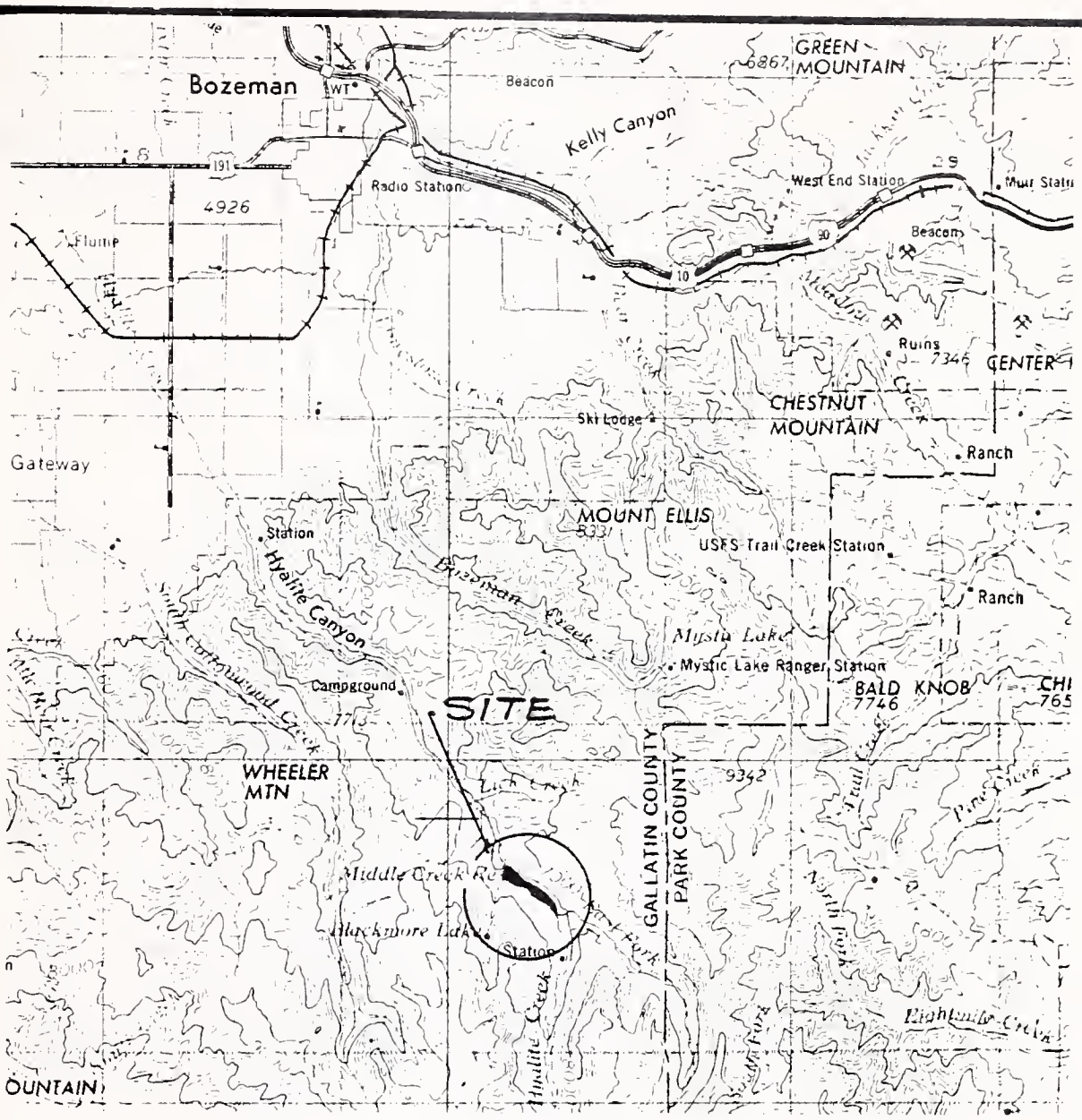
PHOTO 8 Low level conduit discharge

PHOTO 9 Erosion downstream of low level conduit

PHOTO 10 Discharge from left abutment
12-inch diameter toe drain

PHOTO 11 View of downstream slope from left abutment

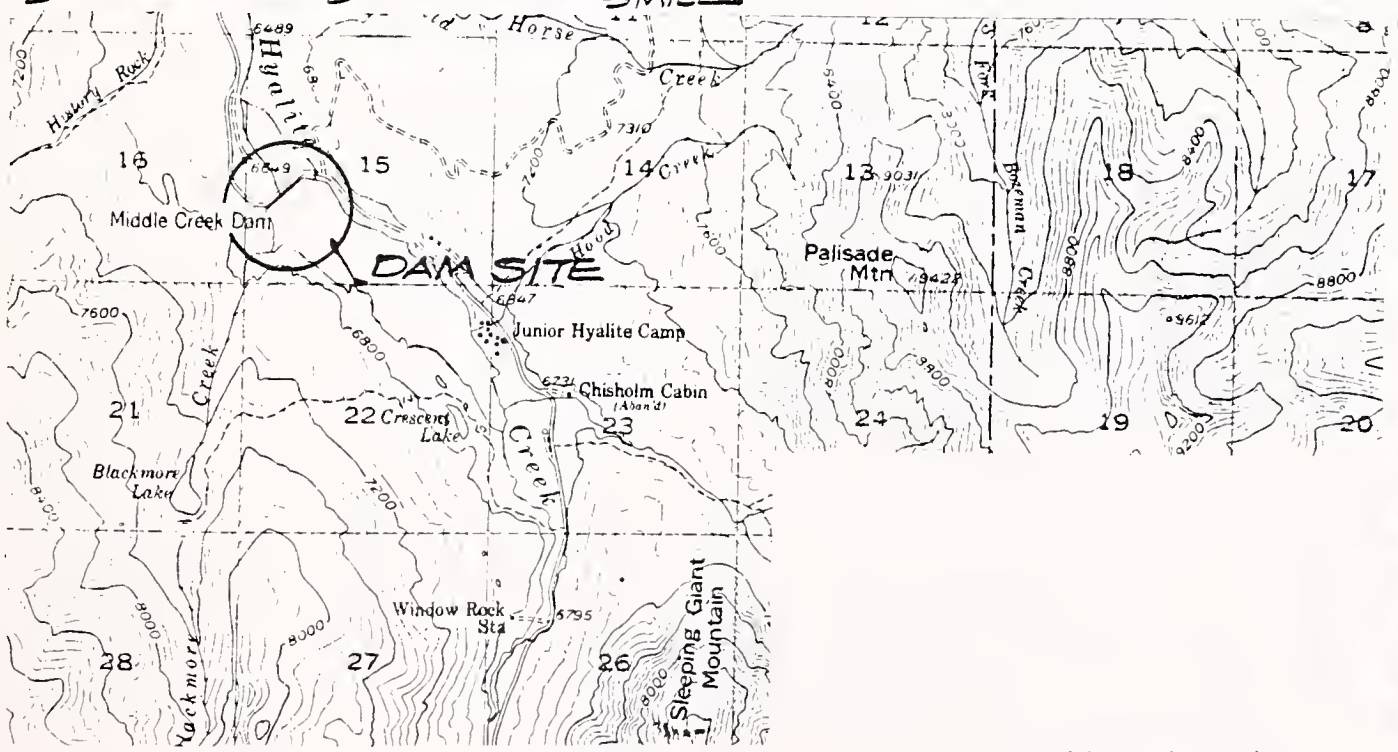
PHOTO 12 View of downstream slope looking at low level conduit discharge and erosion area



PLAN

SCALE 1:250,000

5 0 5 MILES



PLAN

SCALE 1:62,500

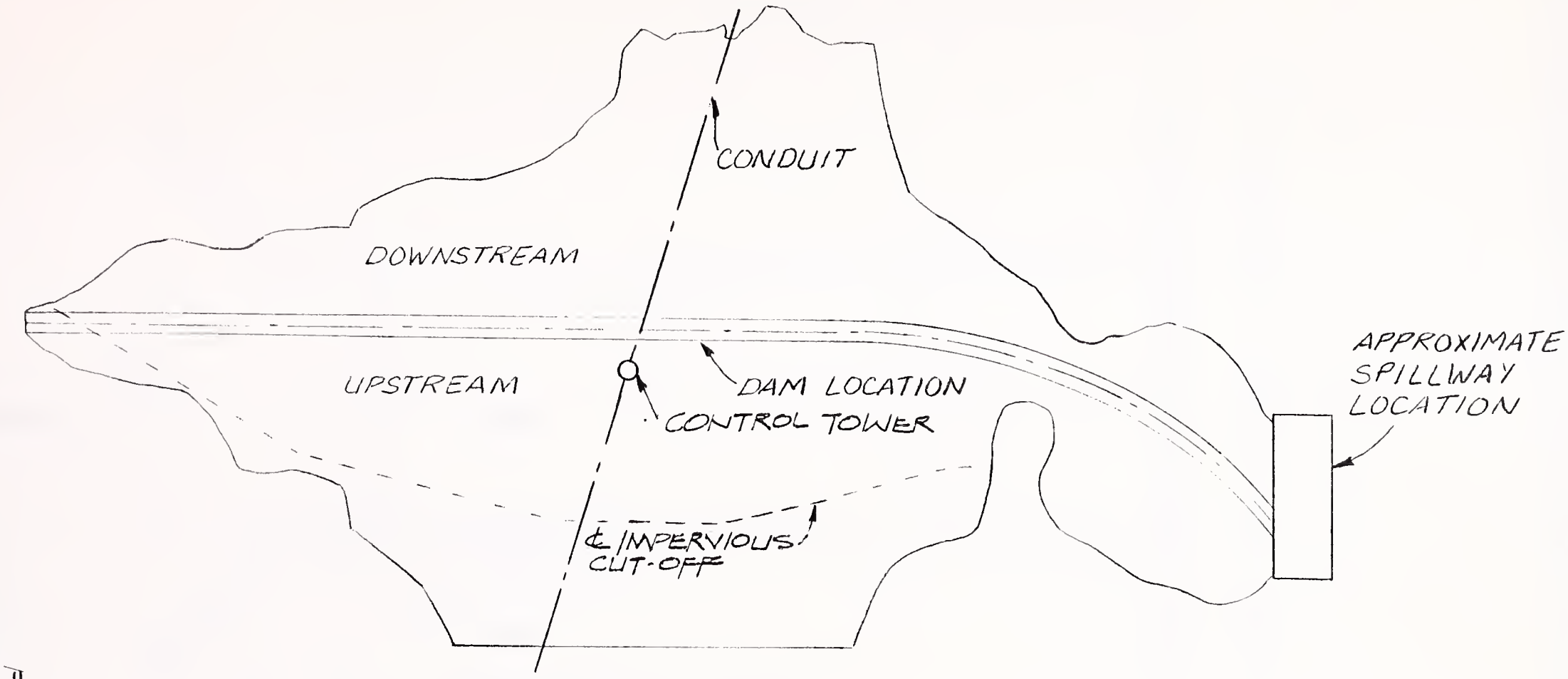
0 1/2 1 MILE

PLATE 1

MIDDLE CREEK DAM

VICINITY MAPS

CH2M HILL



PLAN

N.T.S.

PLATE 2

WOODLE CREEK DAM

SITE PLAN

CH2M HILL

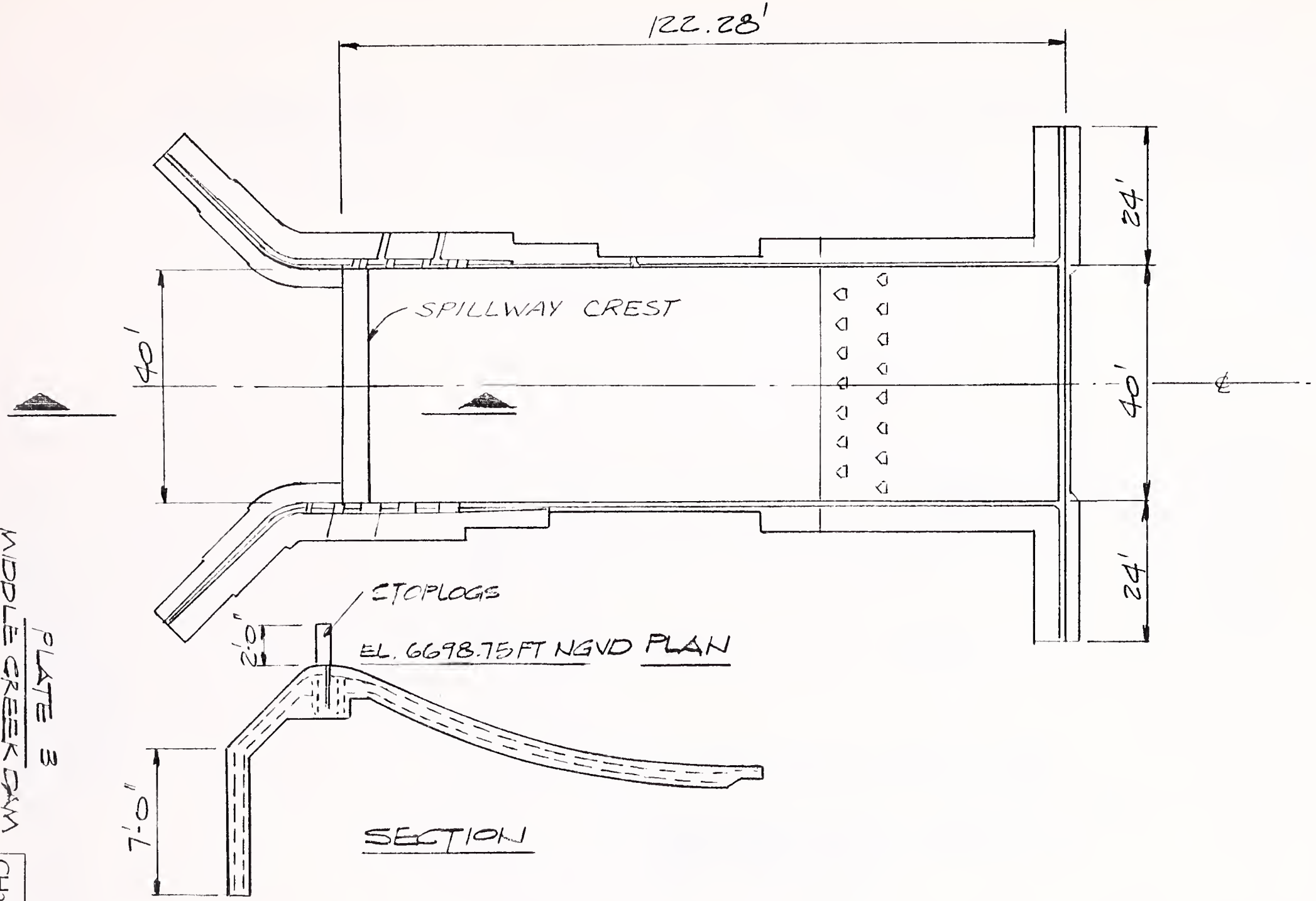


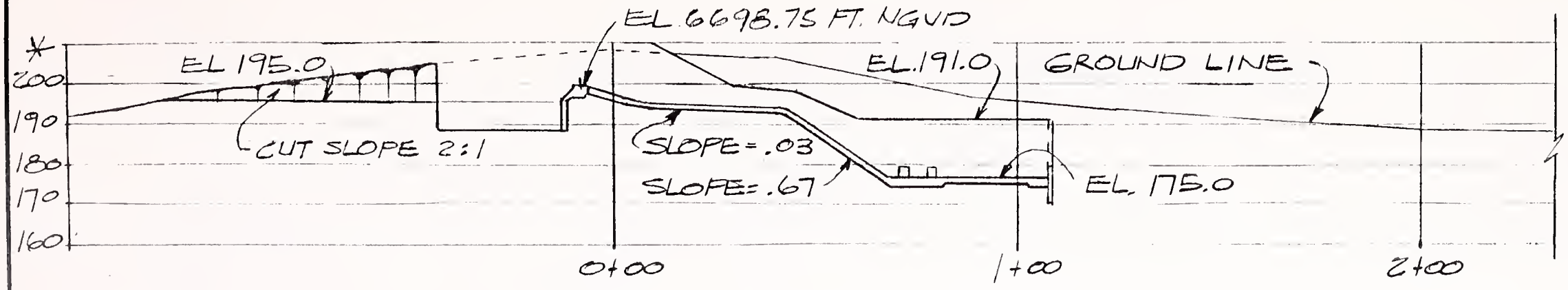
PLATE 3

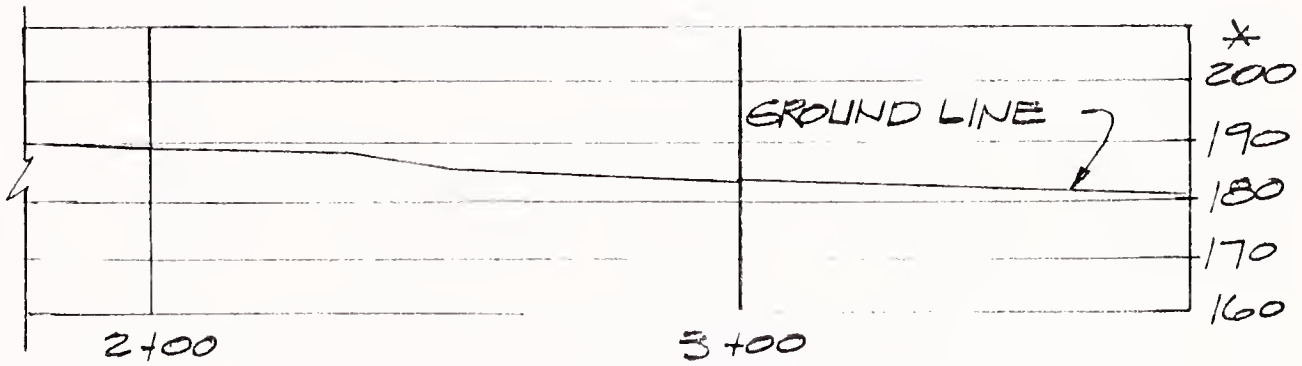
MIDDLE CREEK DAM

SPILLWAY

PLAN & SECTION

CH2M HILL





PROFILE OF SPILLWAY

* ASSUMED DATUM. ELEVATION 210
ASSUMED DATUM IS EQUAL TO
6710 FT NGVD

PLATE 4

MIDDLE CREEK DAM
SPILLWAY PROFILE

CH2M HILL

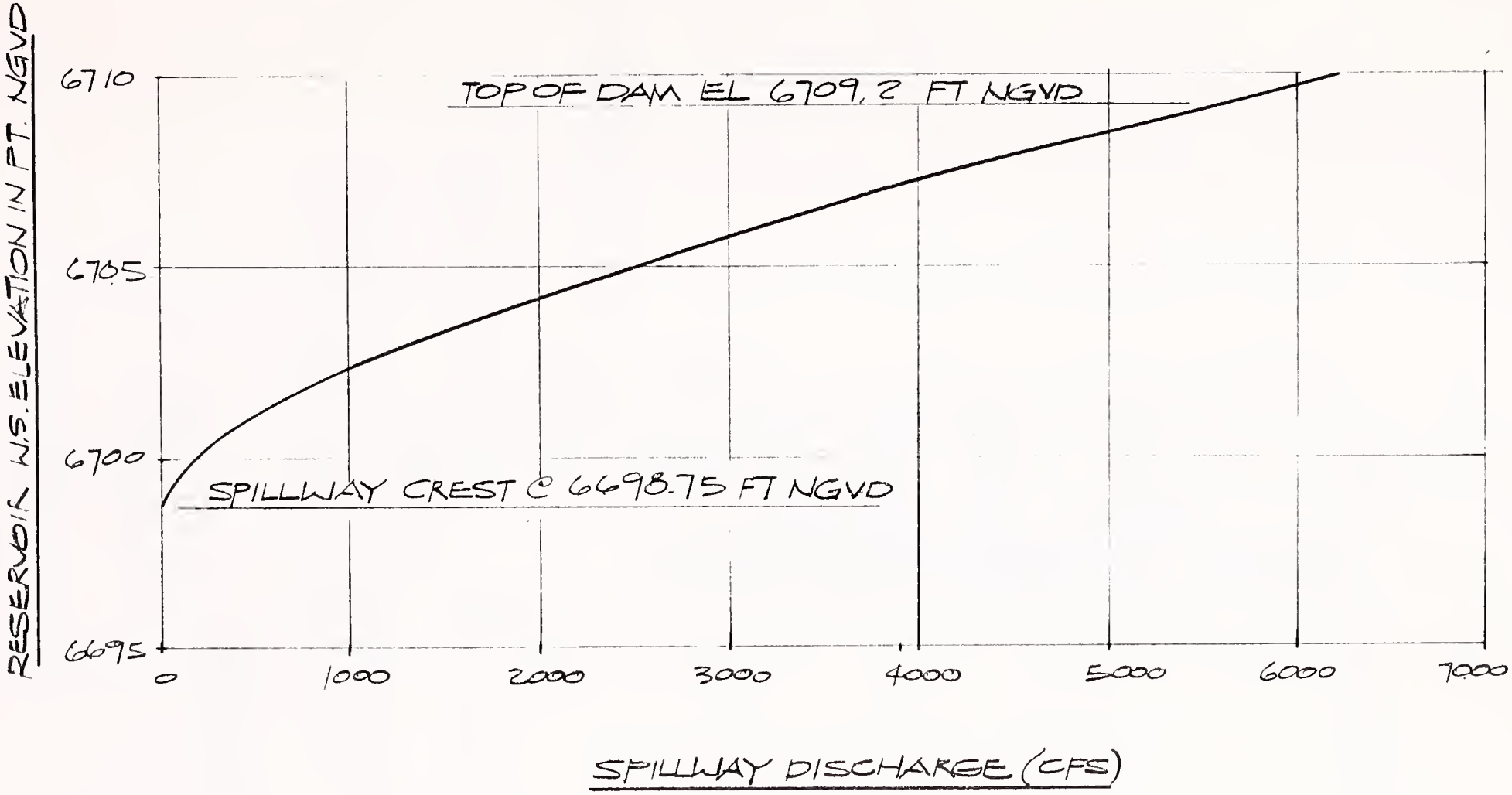
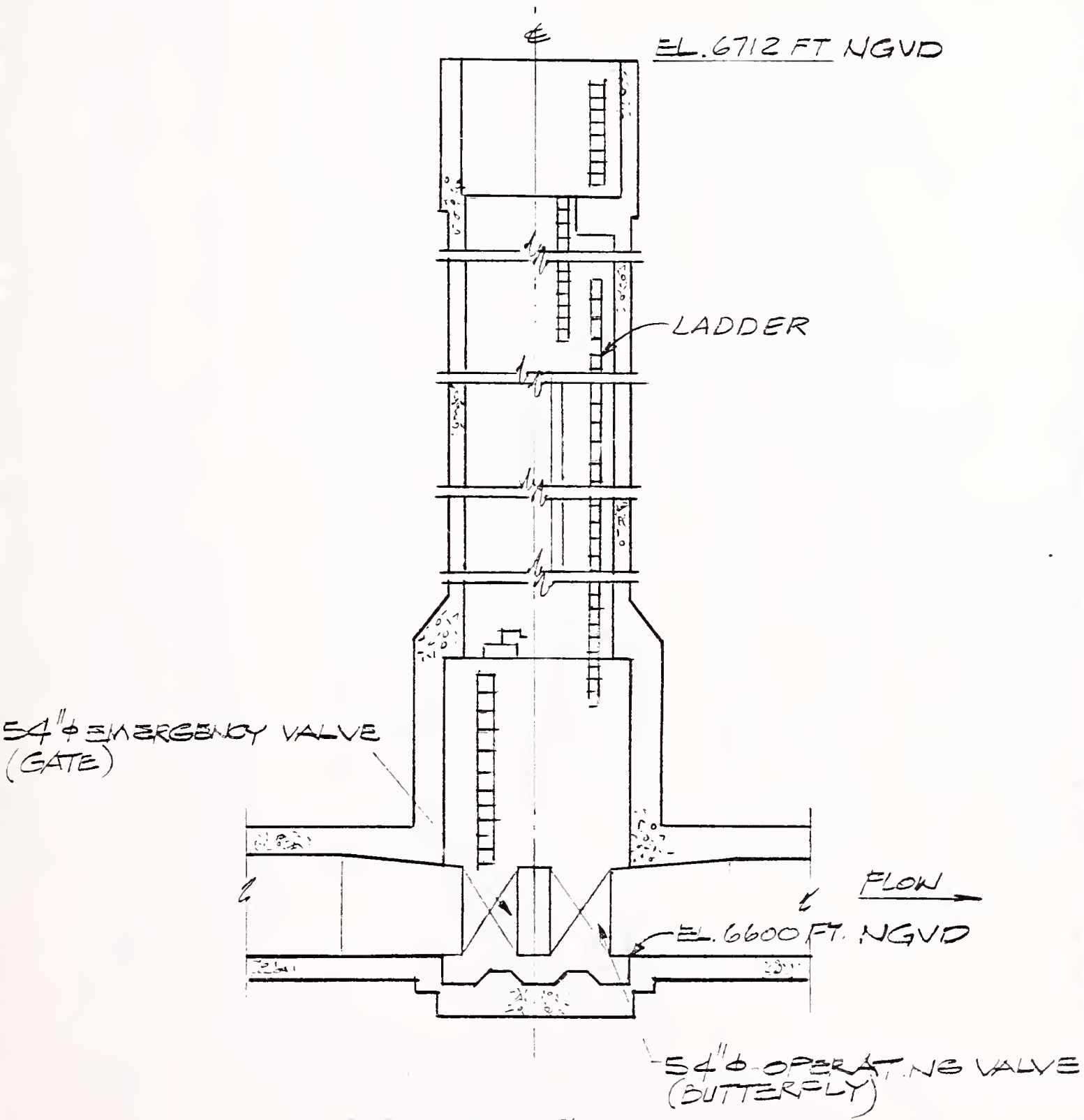


PLATE 5

MIDDLE CREEK DAM

SPILLWAY RATING CURVE

CH2M HILL

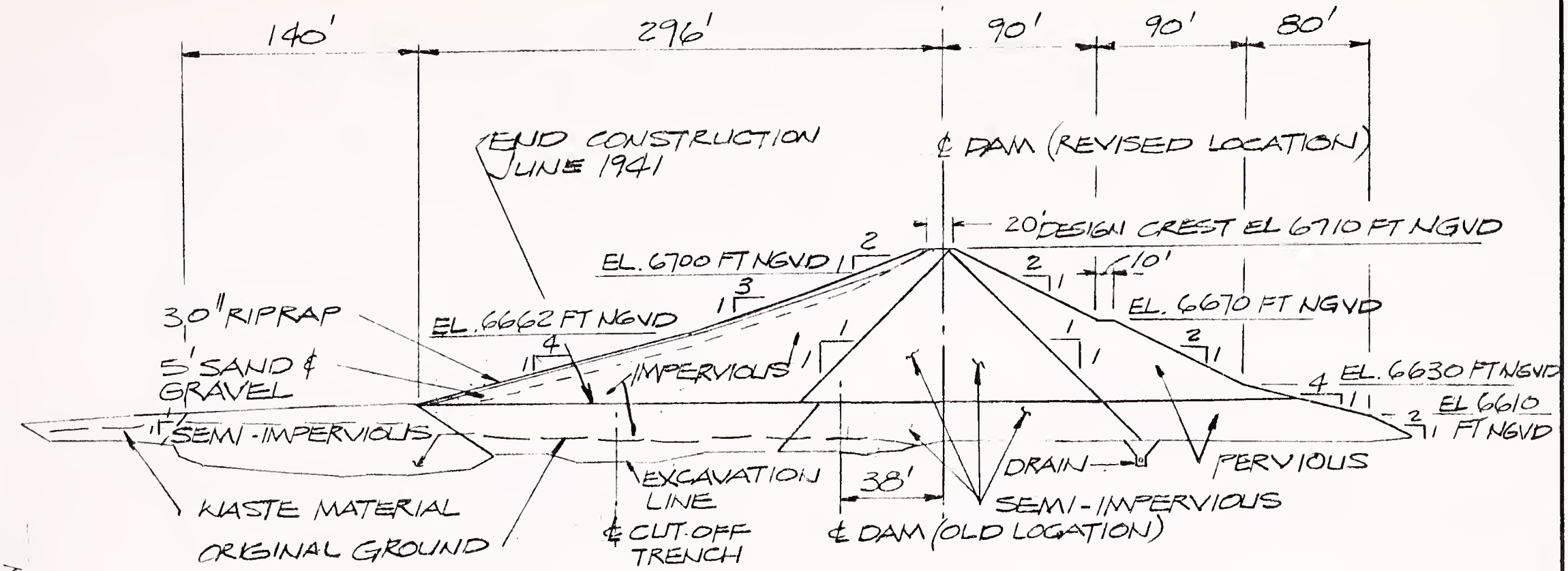


SECTION
N.T.S.

PLATE 6

MIDDLE CREEK DAM
OUTLET WORKS CONTROL

CH2M HILL



DAM EMBANKMENT SECTION

(MEASURED CREST ELEVATION IS 6709.2)

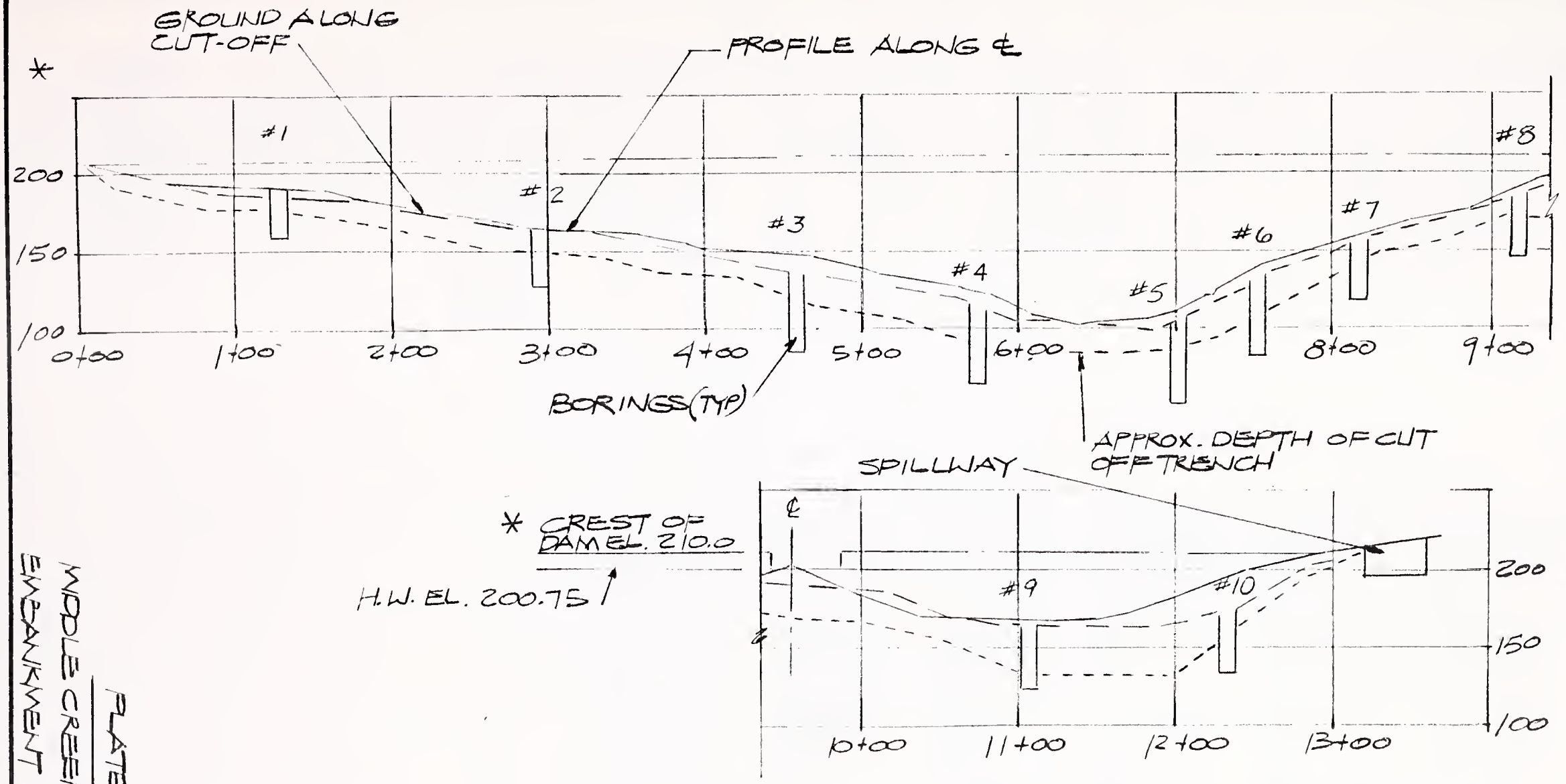
CUTOFF CONFIGURATION IS UNKNOWN)

PLATE 7

MIDDLE CREEK DAM

DAM EMBANKMENT SECTION

CH2M HILL



PROFILE
NTS

* ELEVATIONS TO ASSUMED DATUM - ELEVATION 210 ASSUMED DATUM IS EQUAL TO 6710 FT NGVD

PLATE 8

MIDDLE CREEK DAM
EMBANKMENT PROFILE

CH2M HILL

#1 Top Soil
Yellow Clay
Boulders
Yellow Clay Rock
Boulders-Congl.
Yellow Clay & Rock
Boulders Congl.
Yellow Clay & Rock
Hard Boulders

#2 Top Soil
Yellow Clay & Congl.
Boulders
Yellow Clay
Hard Congl. Boulders

#3 Yellow Clay
Granite Boulders
Yellow Clay-Congl.
Yellow Clay Congl.
Boulder & Congl.
Blue Clay-Broken Rock

#4 Top Soil
Sand & Gravel
Yellow Clay
Blue Clay
Blue Clay
Hard Congl.
Sticky Blue Clay

#5 Top Soil
Yellow Clay & Gravel
Yellow Clay
Boulder & Congl.
Broken Rock & Clay
Yellow Clay
Broken Boulders
Sticky Blue Clay
Blue Clay-Broken Rock
Boulder-Conglomerate
Blue Clay Dry & Hard

#6 Top Soil
Soft Clay
Boulder-Congl.
Yellow Clay
Blue Clay & Rock
Blue Clay & Rock
Hard Rock

#7 Top Soil
Soft Yellow Clay
Hard Congl. Clay
Medium Hard Clay

#8 Top Soil
Yellow Clay
Boulder Conglomerate
Yellow Clay
Boulder-Conglomerate
Yellow Clay

#9 Top Soil-Marsh
Blue Clay-Vegetation
Sand & Gravel
Muck-Blue Clay & Gravel
Medium Hard Conglomerate

#10 Top Soil
Yellow Clay
Boulder & Conglomerate
Yellow Clay
Hard Boulders Conglomerate
Medium Hard Conglomerate

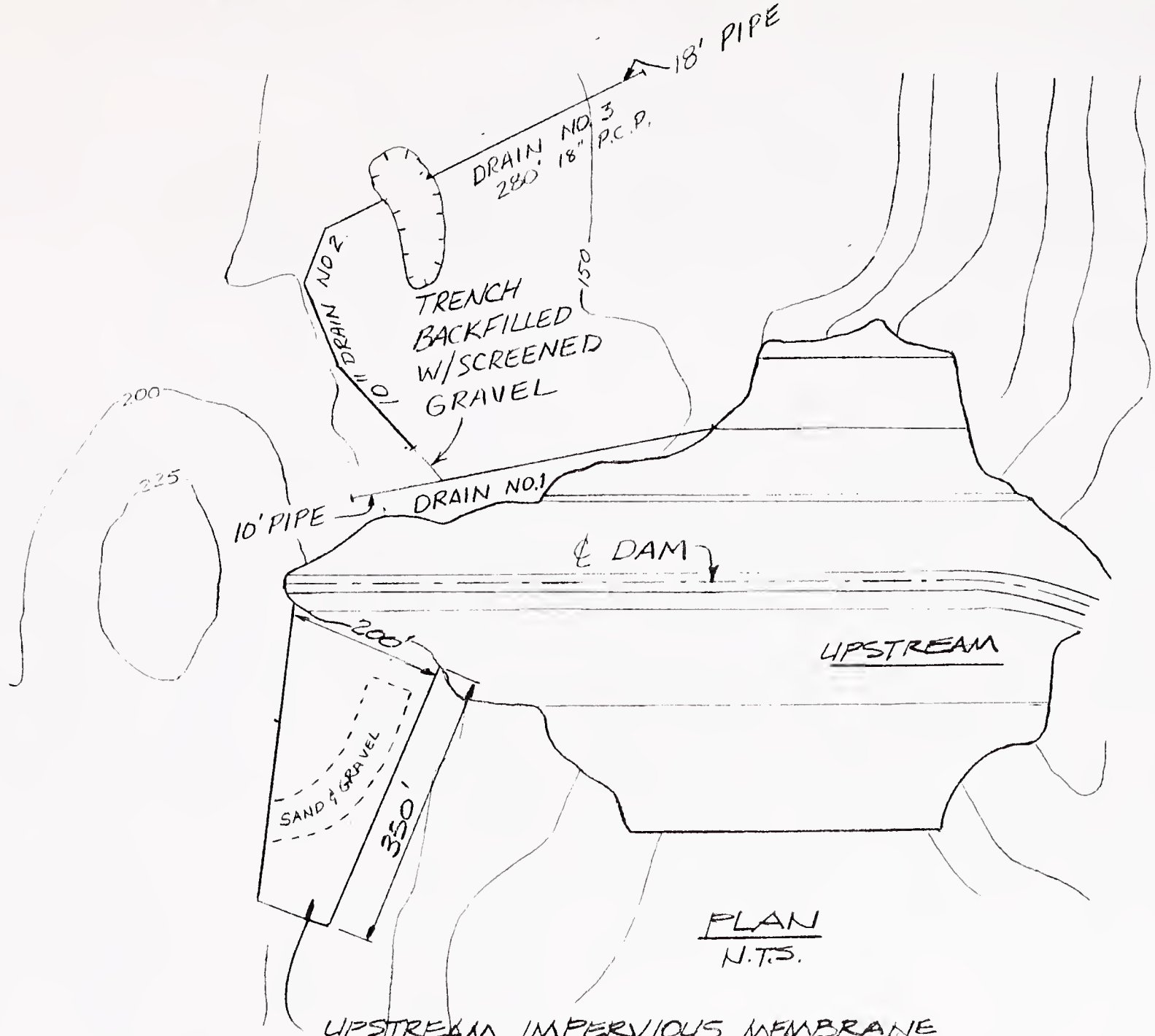
#11 Top Soil
Yellow Clay-Sand & Gravel
Blue Clay-Broken Rock
Blue Clay-Broken Rock

#12 Top Soil
Yellow Clay-Rock
Conglomerate Boulders
Yellow Clay-Broken Rock
Blue Clay-Broken Rock
Blue Clay-Broken Rock

#13 Top Soil
Yellow Clay-Sand & Gravel
Yellow Clay-Broken Rock
Blue Clay-Broken Rock
Basalt-Conglomerate
Yellow Clay-Conglomerate

PLATE 9
MIDDLE CREEK DAM
BORING LOG DESCRIPTION

CH2M HILL



PLAN
N.T.S.

UPSTREAM IMPERVIOUS MEMBRANE CONSTRUCTION IN 1956

SEE PAGE COLLECTION SYSTEM

PLATE 10.

MIDDLE CREEK DAM

CH2M HILL